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ABSTRACT

This paper documents a school building energy efficiency and sustainability project involving the Newport Mesa Unified School District, Southern California Edison's Design and Engineering Services (D&ES), and the architectural firm Perkins and Will. The paper first examines the project design objectives and then discusses each of the project elements, including the site design, daylighting issues and models, and systems for natural ventilation and thermal comfort. Also discussed is the use of DOE-2 energy modeling, which was performed in the design development stage in order to develop consensus on a finalized design. The report also lists data on various characteristics of the school building, such as the architectural features; HVAC system; building operation and internal loading; energy use; annual utility costs; and a list of average school day temperatures, which compares the impact of light and dark roofs on indoor temperatures. (Contains 27 figures.) (GR)

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Deborah Weintraub

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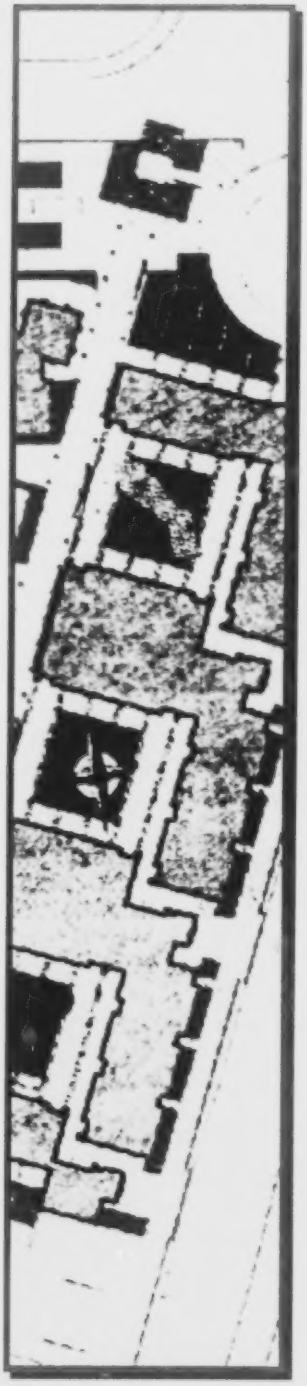
MAINSTREAMING THE SUSTAINABLY DESIGNED SCHOOL



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Southern California Edison
October 16, 1999
Mainstreaming Green
Chattanooga, Tennessee

EF 005 974

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Newport Coast Elementary School

Project Design Objectives:

In late 1997, Southern California Edison's Design and Engineering Services (D&ES) initiated an energy efficiency and sustainability showcase project with the Newport Mesa Unified School District. Named *School of the Future*, D&ES's staff of engineers and architects agreed to consult to the District's design team for the Newport Coast Elementary School, led by the architectural firm of Perkins and Will. The Newport Mesa School District planned to build a new, 25 classroom, K-6th grade campus that would be their first new school built in many years. The site was in an area of new residential development in Newport Beach, with a view of the ocean.

D&ES's role in the project was to facilitate an integrated design approach for all building systems in order to optimize all energy usage, and to improve the environmental performance of the buildings. D&ES focused on an analysis of the classrooms as the basic design module of the school. In terms of interior space conditions, classrooms are by nature of the equipment and number of people in a room, internally loaded spaces. Particularly in the sunny temperate, coastal climate of Newport, this meant that the goals were to reduce the need for electric lighting while minimizing solar heat gain, and to use natural ventilation to achieve thermal comfort, when possible. D&ES agreed to provide:

- Detailed energy modeling using the DOE-2 computer energy simulation program.
- Natural ventilation studies using a graphical air flow visualization technique. The simulated air flows were generated using a computational fluid dynamics simulation program.
- A "green" materials matrix addressing environmental and indoor air quality issues.
- Physical daylighting modeling using ½" scale models with light sensors to measure interior daylighting throughout the year.
- Energy-efficient lighting design and controls.
- Commissioning.
- Post-occupancy monitoring and results reporting.

D&ES's work on the project is funded by Public Goods money collected from all electric ratepayers in California, funds that are earmarked to demonstrate emerging energy-efficiency technologies, and the latest design tools for evaluating buildings.

D&ES worked closely with the Perkins and Will and their team from the very earliest discussions on setting energy and environmental goals and priorities. Early schematic designs were discussed by the team to evaluate the energy impacts of building massing, orientation and siting. The site provided cooling coastal winds for natural ventilation, and good solar exposure for heating when needed, for daylighting and for

renewable energy. It also experienced afternoon marine influenced winds that typically reach up to 15 miles per hour, and a morning marine fog layer.

The climate in Newport Beach is moderate, and the summer daily temperature range is 12°F. The ASHRAE 0.5% summer design conditions for Newport Beach are 80°F dry bulb and 66°F wet bulb[1], with a corresponding relative humidity of approximately 48%. The winter design condition is 39°F and the winter season averages 1,952 heating degree days. The mild temperatures and prevailing breezes typical of the Orange County coast suggested natural ventilation as a dominant means of space cooling for the classrooms.

Perkins and Will established a community design priority that the school have a visible and identifiable physical presence on the main thoroughfare (Newport Coast Drive) that runs along the west side of the site. The land developer in the area, the Irvine Company, asked that the school have an attractive assemblage of red tiled roofs that would be seen from the home sites that would overlook the school, and that the school buildings have no visible rooftop mechanical equipment.

The school district design committee, comprised of teachers, administrators and parents, wanted a school with flexible learning and teaching environments that would accommodate all the new computer technology, classrooms with individual control over space conditioning, good storage, and commodious teacher workspaces.

D&ES ran focus groups jointly with the RAND Corporation to better explore the goals of the teachers and the administrators in Newport, and to gauge their interest in energy and environmental priorities for the new building. In general, the teachers and the school administrators were very interested in multiple means for teachers to control their individual classes for space temperature, outside air, mechanical ventilation, lighting and daylighting. Personal control issues also extended to the desire to have teacher flexibility for furniture arrangement and for technology use.

When queried on their views of energy-efficiency, the "...educators were supportive of energy conservation, but did not view it as having an impact on the classroom or life of the school. Teachers said they would rather have energy specialists provide demonstration lessons about renewable energy than have demonstration areas on-site. Teacher and principals viewed the physical plant as affecting student learning only to the extent that the environment could negatively impact student and teacher satisfaction; they did not seem to view the environment as a significant resource that could contribute to student achievement. They emphasized that the important features of a basic learning environment were ventilation, air-conditioning (during Santa Ana winds or summer), minimal noise, and sufficient space."[2]

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[1] American Society of Heating, Refrigerating & Air-Conditioning Engineers, Inc., Southern California and Golden Gate Chapters, Climatic Data for Region X, Fifth Edition, ASHRAE, 1982, Alhambra, CA.

[2] Evaluating the Effects of School Facilities on Educational Outcomes: A Research Proposal for the *School of the Future* Project; pg. 21; Steve Klein, Tammi Chun; Joy Goodwin; and Peter Scott; RAND; November 17, 1998.

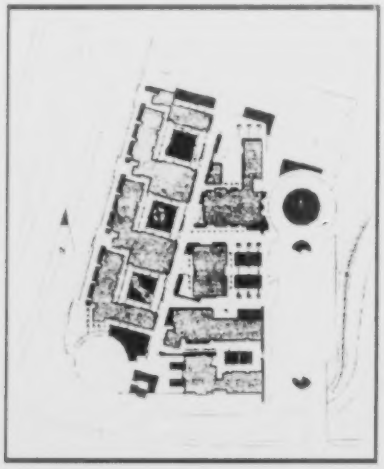
In addition, it is interesting to note that, "Principals did not view renewable energy as a cost savings because their schools are not considered cost centers, since utilities are billed to the district office. Principals saw the benefit as one of virtue: modeling conservation for students."[3]

In order to compare the rather small sample of opinions from these focus groups, RAND looked at a national telephone survey conducted in 1998 by Heery International with 1,050 respondents. "Many of the opinions expressed in our focus groups were echoed by this national sample of teachers and principals. Both the Heery sample and our focus group participants expressed a desire for individually controlled heat and air-conditioning, running water and drinking fountains, accessible phones, decent-sized classrooms, an easily supervisable playground, and natural light. Other parallels between the Newport educators and the national sample include the wish for an additional workroom or conference room for teachers, small rooms to conduct pull-out classes, and the desire for electrical outlets, computers, and computer labs."[4]

Like most large, complex architectural projects, the challenge is to address all of the opportunities inherent in the site and the design priorities in a synthesized and integrated design.

Design Assistance, Simulation Tools and Results:

Site Design:



The early discussions on site design focused on solar exposure and wind. In terms of solar gain, it was agreed that in the early morning of the winter months, solar gain from eastern sun for morning warm-up would be advantageous. Otherwise it was more important to limit solar gain for interior comfort, and to achieve daylighting with limited direct beam sunlight. It was also agreed that capturing the cooling winds that come off the ocean from a southwestern direction for natural ventilation in the classrooms would be important, while shielding the rooms from the stronger, late afternoon marine winds. In addition, the Santa Ana windstorms once or twice a year also bring strong, northeastern, hot dry winds.

Figure 1: Site Plan

The final site plan shown here took advantage of the ability in Southern California to plan a school with covered exterior circulation, and used this design approach to

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[3] Evaluating the Effects of School Facilities on Educational Outcomes: A Research Proposal for the *School of the Future* Project; pg. 21; Steve Klein, Tammi Chun; Joy Goodwin; and Peter Scott; RAND; November 17, 1998.
[4] Evaluating the Effects of School Facilities on Educational Outcomes: A Research Proposal for the *School of the Future* Project; pg. 24-25; Steve Klein, Tammi Chun; Joy Goodwin; and Peter Scott; RAND; November 17, 1998.

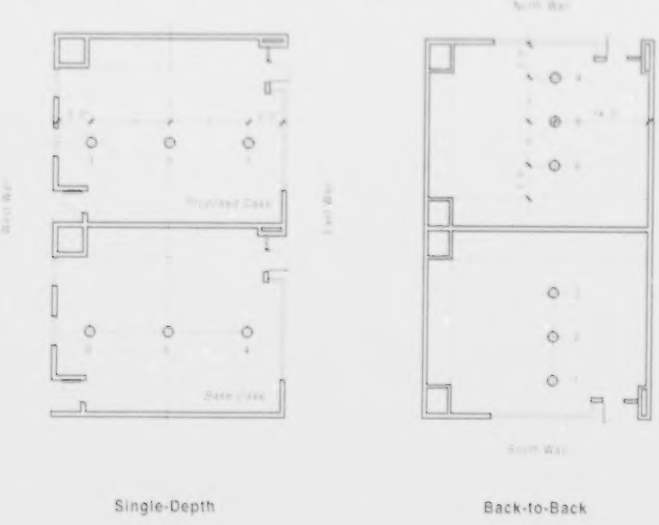
respond to the site's intrinsic environmental opportunities. The site plan did not rigidly interpret the solar and wind analyses, and this allowed the architects to meet other important community design objectives.

By breaking the school into classroom courtyards, the design team created an easy connection between interior and protected exterior teaching spaces. For D&ES, the site plan created three types of classroom spaces that were to be analyzed: Back to Back/North and South Exposure Rooms; Single Depth/East and West Exposure Rooms; and Single Depth/North and South Exposure Rooms.

Daylighting:

The physical daylight modeling was performed on ½" scale models of the Back-to-Back/North and South Exposure Rooms, and the Single-Depth/East and West Exposure Rooms. It was assumed that solutions for the other classrooms, Single Depth/North and South exposure, could be extrapolated from these investigations. Light meter devices (Licor Sensors) were placed at regular intervals inside the models, with an additional sensor above the model in a horizontal position to measure total, unobstructed illuminance. The models were then rotated on a tilt table in direct sunlight to simulate key times throughout the year (June 21st, March 21st, and December 21st).

The following shows the plans of each of the classroom types tested.



Single-Depth Back-to-Back

Figure 2: Licor Configurations

Daylight Modeling on the Single-Depth/East and West Exposure Classrooms:

For the Single-Depth/East and West Exposure Rooms, the model testing addressed two alternatives: the Base Case, or the ceiling plane configuration as designed at that point by the architects; and the Proposed Case. The following sections show the two alternatives.

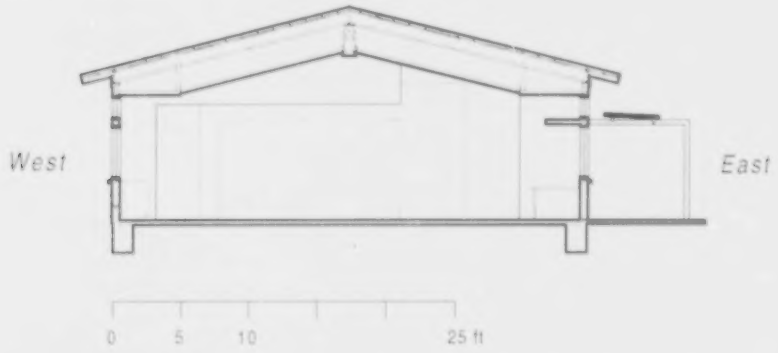


Figure 3: Section of Base Case Single-Depth/East and West Exposure Rooms

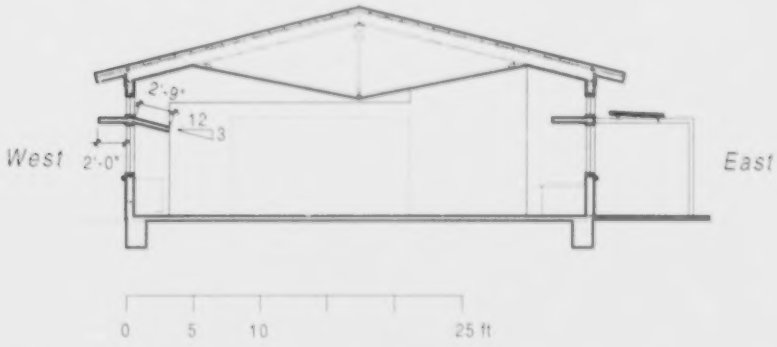


Figure 4: Section of Proposed Single-Depth/East and West Exposure Rooms

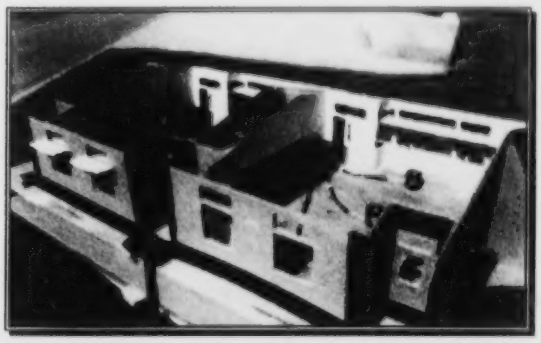


Figure 5: Single-Depth Model with Ceiling Removed

The data collected from the Base Case Single-Depth classroom indicated sufficient daylight penetration into the classroom, but in inconsistent amounts through the course of a day. The testing indicated an unacceptable potential for glare, contrast and direct beam "hotspots" resulting from the morning eastern sun and the afternoon western sun. The Proposed design slightly reduced the overall amount of daylight reaching the classroom, as a result of the additional exterior light shelves, but still maintained adequate footcandle levels, and provided a more consistent level of daylight across the room.

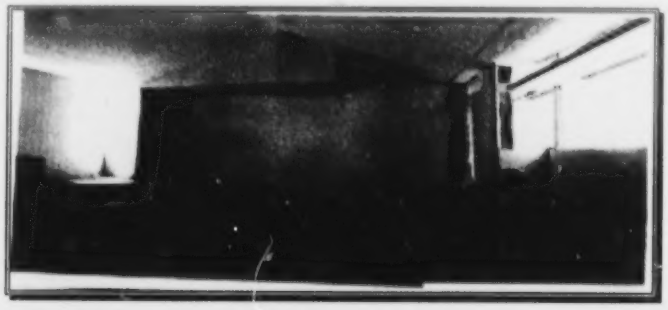


Figure 6: Interior Photo of Single-Depth Base Case Model, Winter Solstice, Dec. 21, 3:00 pm

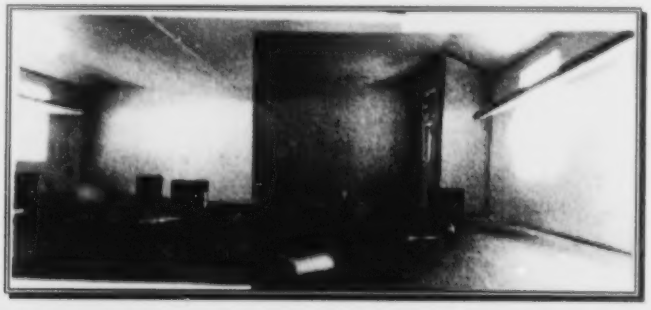


Figure 7: Interior Photo of Single-Depth Proposed Model, Winter Solstice, Dec. 21, 3:00 pm

The photos of the models above demonstrate visually the benefits of the Proposed ceiling configuration. The chart in Figure 9 shows the measured footcandle levels for the Proposed Case and the Base Case, for each Licor location. Also noted is the unobstructed illuminace (Eh), the footcandles corrected for a glazing visible transmittance of 73%, and the daylight factors and corrected daylight factors.[5] The daylight factors were compared to the recommendations from Millet and Bedrick, 1980, as noted in Figure 8. For this project, an acceptable average daylight factor value was targeted at 1.5% or higher.

[5] The final design used clear float glass, with a visible transmittance of approximately 90%.

Figure 8: Recommended Daylight Factors
(Use smaller DF values in southern latitudes with plentiful winter daylight.)

Task	Daylight Factor
Ordinary seeing tasks such as reading, filing, and easy office work.	1.5-2.5%
Moderately difficult tasks, such as prolonged reading, stenographic work, and normal machine tool work.	2.5-4.0%
Difficult, prolonged tasks, such as drafting, proofreading poor copy, fine machine work, and fine inspection.	4.0-8.0%

Figure 9: Single-Depth Base Case and Single-Depth Proposed Case Measured Data

Single-Depth Base Case and Single Depth Proposed Case Data

		Proposed Case			Base Case			
		Licor Sensor #			Licor Sensor #			
Raw Footcandles		S1	S2	S3	S4	S5	S6	Eh
	Dec 21 (WS) 9:00 am	451.70	104.90	64.31	1858.00	571.80	90.60	2545
	Dec 21 (WS) Noon	153.60	43.17	41.21	150.60	44.55	61.63	3554
	Dec 21 (WS) 3:00 pm	71.80	35.49	85.30	83.60	41.15	109.30	2860
	Mar 21 (EQ) 9:00 am	291.30	73.40	49.35	288.70	73.70	67.78	4086
	Mar 21 (EQ) Noon	115.80	36.83	44.80	114.90	38.98	70.00	4625
	Mar 21 (EQ) 3:00 pm	66.23	39.79	123.60	68.65	47.27	165.20	3813
	Jun 21 (SS) 9:00 am	240.30	60.16	45.74	201.60	59.67	61.97	4422
	Jun 21 (SS) Noon	92.70	29.32	52.25	85.60	29.98	81.90	4808
	Jun 21 (SS) 3:00 pm	62.68	43.02	151.80	68.92	54.34	232.10	4523
Corrected Footcandles								
VT=73%								
	Dec 21 (WS) 9:00 am	329.74	76.58	46.95	1356.34	417.41	66.14	
	Dec 21 (WS) Noon	112.13	31.51	30.08	109.94	32.52	44.99	
	Dec 21 (WS) 3:00 pm	52.41	25.91	62.27	61.03	30.04	79.79	
	Mar 21 (EQ) 9:00 am	212.65	53.58	36.03	210.75	53.80	49.48	
	Mar 21 (EQ) Noon	84.53	26.89	32.70	83.88	28.46	51.10	
	Mar 21 (EQ) 3:00 pm	48.35	29.05	90.23	50.11	34.51	120.60	
	Jun 21 (SS) 9:00 am	175.42	43.92	33.39	147.17	43.56	45.24	
	Jun 21 (SS) Noon	67.67	21.40	38.14	62.49	21.89	59.79	
	Jun 21 (SS) 3:00 pm	45.76	31.40	110.81	50.31	39.67	169.43	
Daylight Factors								
	Dec 21 (WS) 9:00 am	17.7%	4.1%	2.5%	73.0%	22.5%	3.6%	
	Dec 21 (WS) Noon	4.3%	1.2%	1.2%	4.2%	1.3%	1.7%	
	Dec 21 (WS) 3:00 pm	2.5%	1.2%	3.0%	2.9%	1.4%	3.8%	
	Mar 21 (EQ) 9:00 am	7.1%	1.8%	1.2%	7.0%	1.8%	1.7%	
	Mar 21 (EQ) Noon	2.5%	0.8%	1.0%	2.5%	0.8%	1.5%	
	Mar 21 (EQ) 3:00 pm	1.7%	1.0%	3.2%	1.8%	1.2%	4.3%	
	Jun 21 (SS) 9:00 am	5.4%	1.4%	1.0%	4.6%	1.3%	1.4%	
	Jun 21 (SS) Noon	1.9%	0.6%	1.1%	1.8%	0.6%	1.7%	
	Jun 21 (SS) 3:00 pm	1.4%	1.0%	3.4%	1.5%	1.2%	5.1%	
Corrected Daylight Factors								
VT=73%								
	Dec 21 (WS) 9:00 am	13.0%	3.0%	1.8%	53.3%	16.4%	2.6%	
	Dec 21 (WS) Noon	3.2%	0.9%	0.8%	3.1%	0.9%	1.3%	
	Dec 21 (WS) 3:00 pm	1.8%	0.9%	2.2%	2.1%	1.1%	2.8%	
	Mar 21 (EQ) 9:00 am	5.2%	1.3%	0.9%	5.1%	1.3%	1.2%	
	Mar 21 (EQ) Noon	1.8%	0.6%	0.7%	1.8%	0.6%	1.1%	
	Mar 21 (EQ) 3:00 pm	1.3%	0.8%	2.4%	1.3%	0.9%	3.2%	
	Jun 21 (SS) 9:00 am	4.0%	1.0%	0.8%	3.3%	1.0%	1.0%	
	Jun 21 (SS) Noon	1.4%	0.4%	0.8%	1.3%	0.5%	1.2%	
	Jun 21 (SS) 3:00 pm	1.0%	0.7%	2.5%	1.1%	0.9%	3.7%	

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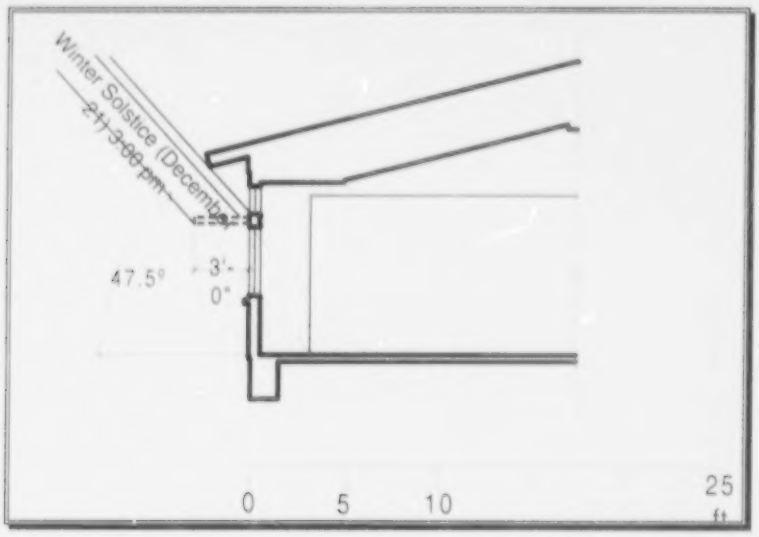

Figure 10: Profile Angle Analysis of Single-Depth West Wall

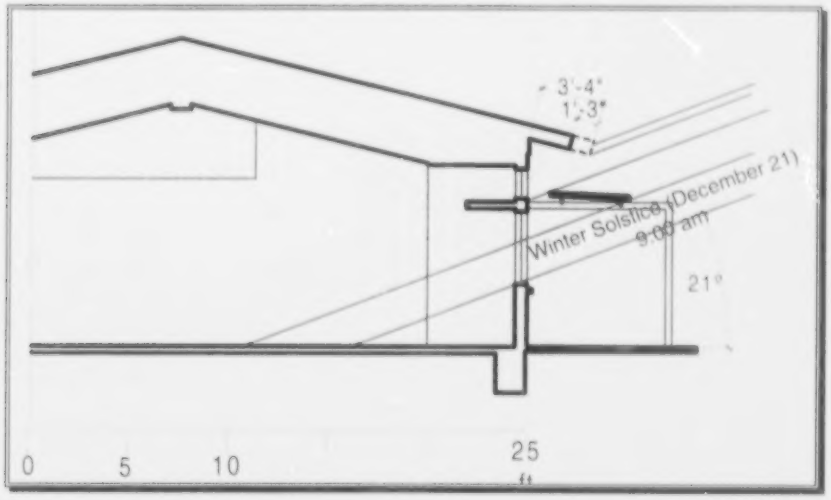

Figure 11: Profile Angle Analysis of Single-Depth East Wall

Figures 10 and 11 show an analysis of the sun's profile angles for direct beam penetration in the Single-Depth classrooms at key times. The drawings indicate proposed solutions. The solutions included a 3'-0" overhang on the West windows, acknowledging that this would not suffice after 3:00 pm, and the extension of the East roof overhang by 1'-3". Again, prior to 9:00 am on December 21st, some direct beam would penetrate the east windows. The architectural solutions are not meant to solve all direct beam problems, but to allow window treatments to be largely unnecessary so that daylight is utilized the majority of the time. The architects could not accommodate the 3'-0" exterior western overhang, and settled for a 1'-6" deep perforated metal exterior and 1'-6" deep fabric interior light shelf combination. This will require the use of blinds on the lower windows in the late afternoon, but will still allow bounced daylight through the upper windows off the interior light shelf. The interior light shelves are

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fabricated with an aluminum frame and a fiberglass solar control fabric that is partially translucent and partially reflective. The interior light shelf was intentionally designed using a light weight material to deter teachers from using the light shelf for storage.

Daylight Modeling on the Back-to-Back/North and South Exposure Classrooms:

The process for evaluating the daylighting in the Back-to-Back classrooms was similar to the Single-Depth classrooms. The images and text below briefly summarizes the conclusions.

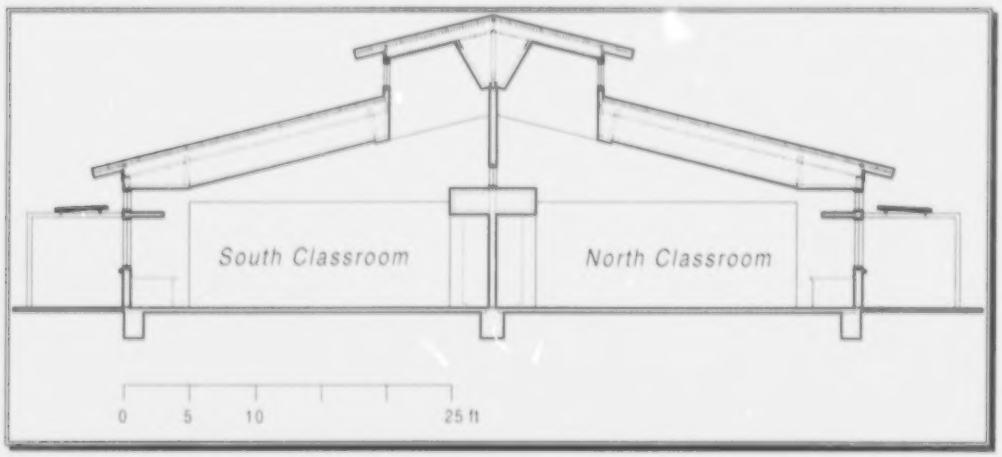

Figure 12: Section of Back-to-Back Base Case Classroom

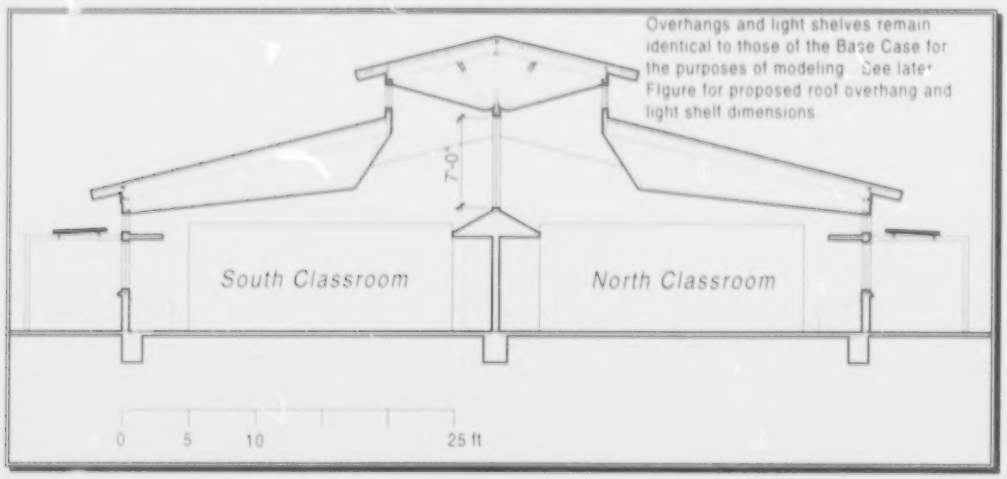
Overhangs and light shelves remain identical to those of the Base Case for the purposes of modeling. See later Figure for proposed roof overhang and light shelf dimensions
7'-0"
South Classroom
North Classroom
0
5
10
25 ft

Figure 13: Section of Back-to-Back Proposed Classroom

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Figure 14: Back-To-Back Proposed Case Measured Data

Back-to-Back Proposed Case Data

		South Classroom			North Classroom			
		Light Sensor #			Light Sensor #			
Raw Footcandles		S1	S2	S3	S4	S5	S6	Eh
	Dec 21 (WS) 9:00 am	102.50	71.40	67.52	87.80	36.64	31.89	2551
	Dec 21 (WS) Noon	305.60	124.10	105.00	107.40	104.70	68.66	3720
	Dec 21 (WS) 3:00 pm	1885.00	169.30	145.80	118.00	76.60	90.00	2648
	Mar 21 (EQ) 9:00 am	136.00	41.43	37.69	116.30	37.43	30.56	3971
	Mar 21 (EQ) Noon	253.10	72.40	58.63	101.00	37.96	30.60	4732
	Mar 21 (EQ) 3:00 pm	245.80	77.30	64.87	146.10	61.74	53.00	4056
	Jun 21 (SS) 9:00 am	102.60	41.93	37.69	202.60	55.94	43.35	4439
	Jun 21 (SS) Noon	134.50	45.08	39.68	148.90	43.07	32.70	5074
	Jun 21 (SS) 3:00 pm	162.30	47.14	38.92	149.00	47.20	36.08	4583
Corrected Footcandles								
VT=73%								
	Dec 21 (WS) 9:00 am	140.53	52.12	45.64	64.09	25.94	23.27	
	Dec 21 (WS) Noon	225.09	90.59	76.65	78.40	76.43	50.12	
	Dec 21 (WS) 3:00 pm	1376.05	123.59	106.43	86.14	55.92	65.70	
	Mar 21 (EQ) 9:00 am	99.28	30.24	27.51	86.36	27.32	22.31	
	Mar 21 (EQ) Noon	184.76	52.85	42.80	73.73	27.71	22.34	
	Mar 21 (EQ) 3:00 pm	179.43	56.43	47.36	106.65	45.07	38.69	
	Jun 21 (SS) 9:00 am	74.83	30.61	27.51	147.90	40.84	31.65	
	Jun 21 (SS) Noon	98.19	32.91	28.97	108.70	31.44	23.87	
	Jun 21 (SS) 3:00 pm	118.48	34.41	28.41	108.77	34.46	26.34	
Daylight Factors								
	Dec 21 (WS) 9:00 am	7.5%	2.6%	2.5%	3.4%	1.4%	1.2%	
	Dec 21 (WS) Noon	8.2%	3.3%	2.8%	2.9%	2.8%	1.8%	
	Dec 21 (WS) 3:00 pm	69.2%	5.9%	5.1%	4.1%	2.7%	3.2%	
	Mar 21 (EQ) 9:00 am	3.4%	1.0%	0.9%	3.0%	0.9%	0.8%	
	Mar 21 (EQ) Noon	5.3%	1.5%	1.2%	2.1%	0.8%	0.6%	
	Mar 21 (EQ) 3:00 pm	6.1%	1.9%	1.6%	3.6%	1.5%	1.3%	
	Jun 21 (SS) 9:00 am	2.3%	0.9%	0.8%	4.6%	1.3%	1.0%	
	Jun 21 (SS) Noon	2.7%	0.9%	0.8%	2.9%	0.8%	0.6%	
	Jun 21 (SS) 3:00 pm	3.5%	1.0%	0.8%	3.3%	1.0%	0.8%	
Corrected Daylight Factors								
VT=73%								
	Dec 21 (WS) 9:00 am	5.5%	2.0%	1.8%	2.5%	1.0%	0.9%	
	Dec 21 (WS) Noon	6.0%	2.4%	2.1%	2.1%	2.1%	1.3%	
	Dec 21 (WS) 3:00 pm	48.3%	4.3%	3.7%	3.0%	2.0%	2.3%	
	Mar 21 (EQ) 9:00 am	2.5%	0.8%	0.7%	2.2%	0.7%	0.6%	
	Mar 21 (EQ) Noon	3.9%	1.1%	0.9%	1.6%	0.6%	0.5%	
	Mar 21 (EQ) 3:00 pm	4.4%	1.4%	1.2%	2.6%	1.1%	1.0%	
	Jun 21 (SS) 9:00 am	1.7%	0.7%	0.6%	3.3%	0.9%	0.7%	
	Jun 21 (SS) Noon	1.9%	0.6%	0.6%	2.1%	0.6%	0.5%	
	Jun 21 (SS) 3:00 pm	2.6%	0.8%	0.6%	2.4%	0.8%	0.6%	

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In the Back-to-Back classrooms, the results of the modeling indicated that the Proposed section resulted in an overall increase in interior illuminance levels, and in the quality of the light. The interior window between the south facing and north facing classroom was crucial for the daylighting in the north classroom. It served to increase illuminance in the north classroom by as much as 350% (on the Winter solstice, Dec. 21st at 3:00 pm). There were direct beam issues in the winter months, suggesting deeper roof overhangs, wider exterior walkway roofing, or the use of interior window treatments on the lower vision glazing, and on the interior window between the south and north classroom. The architects chose to widen the exterior walkway roofing to 5'-0", and extend the roof overhang to 2'-6" on the lower vision windows and on the monitor windows.

For the interior window between the Back-to-Back classrooms, much discussion ensued as to the most effective glazing material. With the computers in the north classroom planned for the north exterior wall with the monitors facing the interior window, there was concern that a translucent glazing on the interior window would create a distinct image on the computer monitors. Finally it was concluded that the interior glazing material should be clear, with the ability to block the daylight using interior shades.

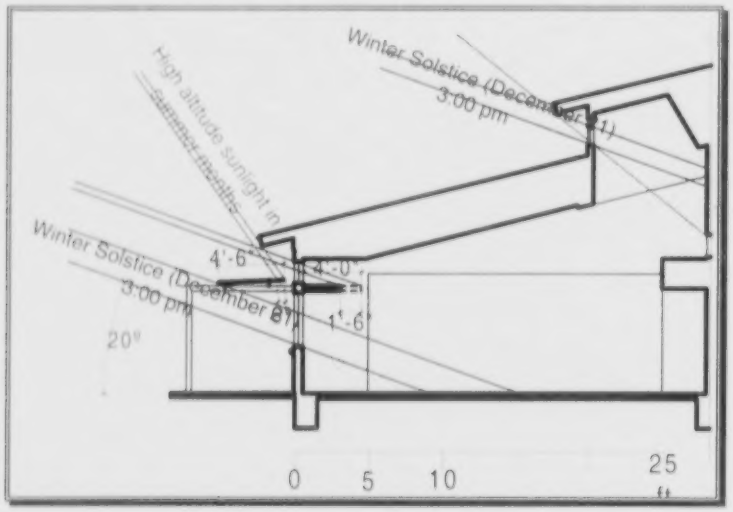

Figure 15: Profile Angle Analysis of Back-To-Back Classroom, South Wall

Natural Ventilation and Thermal Comfort Analysis:

Conditioning the indoor environment for human thermal comfort is a building science that is often more about statistical probability than applied engineering principles. The individual perceptions of thermal comfort within even small groups of occupants are

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often widely divergent. ASHRAE's definition recognizes the individual occupant's role in defining thermal comfort:

"Thermal Comfort is that condition of mind that expresses satisfaction with the thermal environment."[6]

The variables affecting human comfort include the individual's metabolic rate and clothing type, space air temperature and relative humidity, air velocity, surface temperatures of the objects within the space, the direct radiation of sunlight, and the ambient climatic conditions. Many metrics have been studied to evaluate indoor thermal comfort. For the analysis of thermal comfort in the proposed Newport Coast Elementary School classroom, D&ES used the ASHRAE thermal sensation scale. This scale consists of a numerical value which represents a category of thermal sensation, as follows:

Hot	Warm	Slightly Warm	Neutral	Slightly Cool	Cool	Cold
+3	+2	+1	0	-1	-2	-3

The thermal sensation achieved through the use of natural ventilation, as opposed to mechanical air conditioning, was examined using computational fluid dynamics models. Computational fluid dynamics (CFD) is a method of simultaneously solving the conservation of mass, energy and momentum equations for discrete volumes which are defined within the modeled space. The simultaneous solution of these equations allows us to plot and visualize various physical properties within the space. For instance, we can plot distributions of space air temperature, or relative humidity, or air velocity across the modeled area. Thermal sensation is derived from these physical properties and can also be plotted.

A two-dimensional model of the back-to-back classroom form was generated at the summer design ambient dry-bulb temperature of 80° F, with air moving through the classroom at 20 air changes per hour. Fixed louvers below the vision glass were modeled for the ventilation air inlet, and operable monitor windows for the air outlet. The thermal sensation distribution resulting from this simulation is shown in Figure 16. Note that the area surrounding the children's desks is within +/- 0.5 on the thermal sensation scale. Figures 17 and 18 illustrate the temperature and air velocity distributions generated by the CFD analysis. Although the dry bulb temperatures in the vicinity of the students is nearly 81° F, the thermal sensation category is favorable due to the local air velocity. These results allowed D&ES to predict general satisfaction within the indoor environment using natural or mechanical ventilation for this case, even though the District does not currently anticipate using the school during the summer.

[6] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1997 ASHRAE Handbook, Fundamentals, ASHRAE, 1997, Atlanta, GA.

It should be noted that in the final design, ventilation was introduced into the Back-to-Back classrooms through operable vision windows, with fan assisted, hot air removal plenums at the top of the monitor window area. This solution addressed the security concerns of the district with having operable monitor windows.

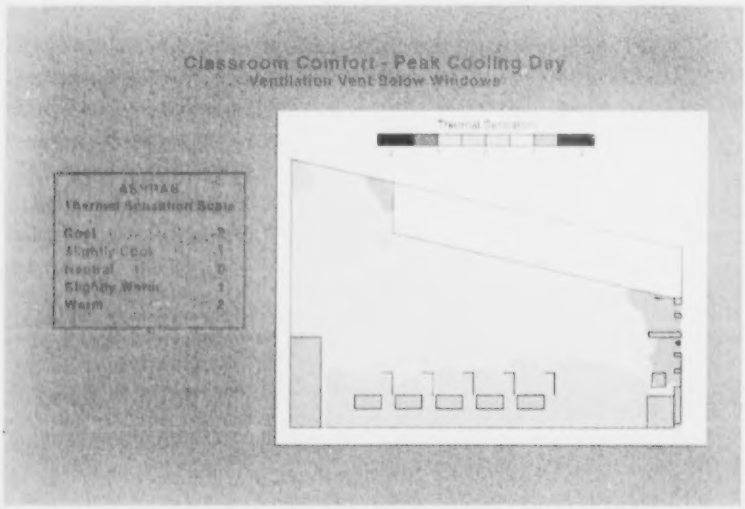

Figure 16: Classroom Comfort:
Peak Cooling Day With Ventilation Vent Below Windows

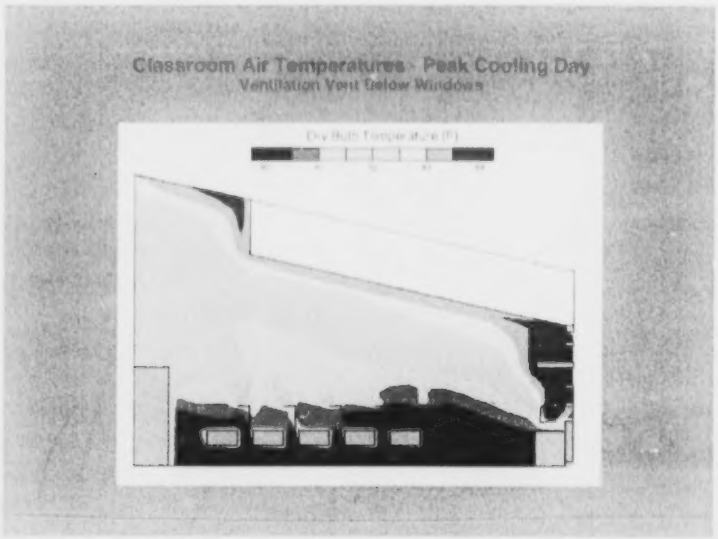

Figure 17: Classroom Air Temperatures:
Peak Cooling Day With Ventilation Vent Below Windows

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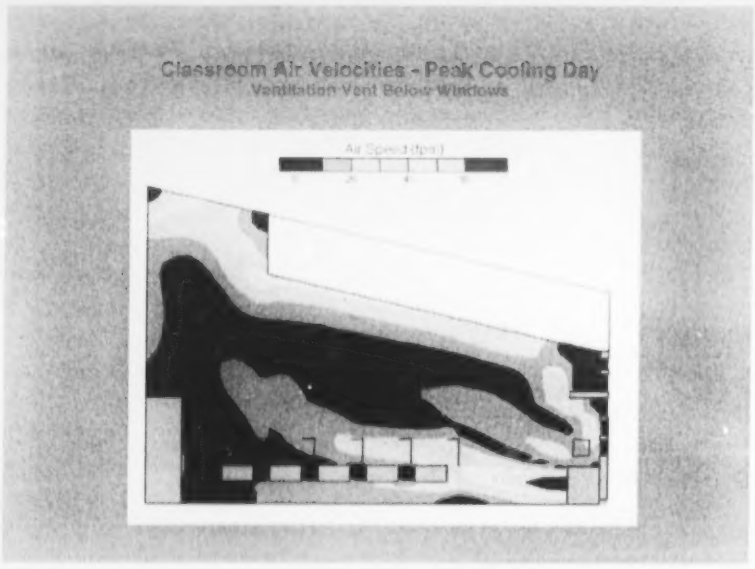

Figure 18: Classroom Air Velocities
Peak Cooling Day With Ventilation Below Windows

As noted earlier in the results of the D&ES/RAND focus groups, the District was not ready to eliminate the air conditioning all together. They have acknowledged that with the predictions from this natural ventilation analysis, the teachers should be taught to operate their classroom as much as possible with natural and mechanically-assisted ventilation, resorting to air conditioning only as a final comfort tool. Teacher and staff orientation to the functioning of the classrooms will fall to the commissioning team and the design team to carry out.

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DOE-2 Energy Modeling:

The DOE-2 energy model was performed in the design development stage of the project, and modeled design alternatives that had been discussed at length with the design team to develop consensus. The DOE-2 input consisted of a detailed description of the building, including all building features such as shading, fenestration, interior building mass, envelope building mass, and the dynamic characteristics of the heating and air conditioning system and controls. It also included all hourly schedules for occupants, lighting, equipment and thermostat settings. This simulation actually used PowerDOE®, an advanced version of DOE-2.1E, which calculates hour-by-hour building energy consumption for an entire year (8,760 hours) using local weather data (California Thermal Zone CTZ6, Long Beach).

The model was developed for the project when it included about 47,000 sq. ft. total, with about 28,000 sq. ft. of classrooms, 4,400 sq. ft. of administrative space, 7,900 sq. ft. for the multipurpose building, 3,400 sq. ft. for the library/media center, and 3,300 sq. ft. of support and toilet facilities. After several project estimations, and final bids, the overall size of the school was reduced.

The image below visually shows the PowerDOE model, with missing building components simulated as multipliers of the buildings that they match.

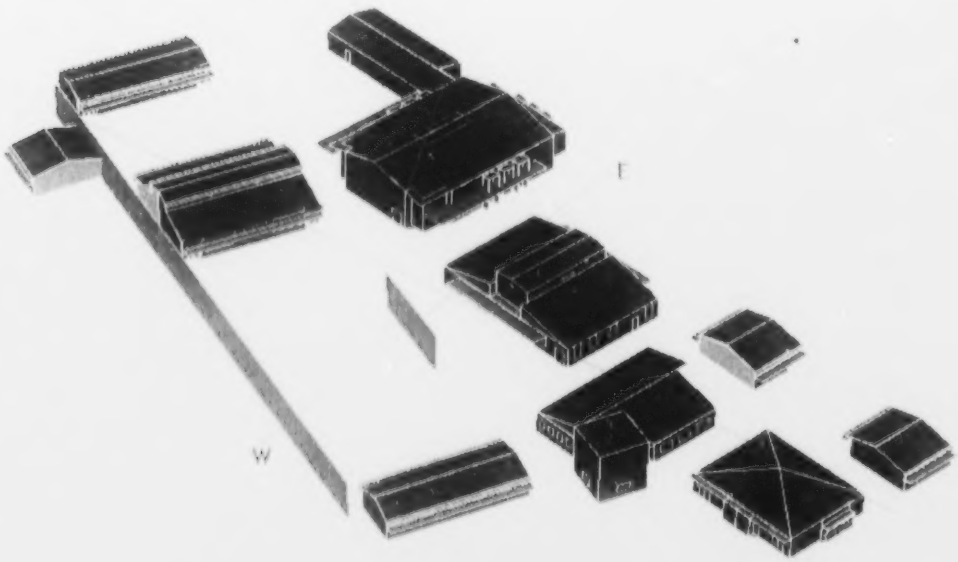


Figure 19: Newport Coast Elementary School PowerDOE Model as Viewed From the Southwest

It was assumed that the lighting, HVAC, and kitchen energy loads represented the majority of the operating costs, and the PowerDOE analysis focused on reducing electric lighting and HVAC operating costs. The iterations in the analysis were for envelope measures, fenestration measures, natural ventilation measures, and HVAC equipment measures. Except where noted in the figures below, each energy-efficiency measure was evaluated "on-top-of" the previous measure, in order to model interactive benefits of the final package of measures. Also, the results of the physical daylight modeling were used to calibrate the PowerDOE model.

Figure 20 summarizes the features of the Base Case building and the Proposed building. Figure 21 shows the operating profiles that were assumed for the building. Figure 22 is the PowerDOE output, measure by measure, for annual energy use, and Figure 23 is the PowerDOE output, measure by measure, for annual cost savings. Close examination of these results showed that the single largest saving occurred when a dimming system was used for the classroom lighting. At this point one sees a total 41% savings in energy and a 39% savings in cost over the base case Title 24 minimum. The dimming represents an additional 37% cost savings over all previous energy-efficiency measures. Also, of particular interest, note that the PowerDOE simulation showed little return for high-efficiency glazing in this climate, and given the cost of these glazing alternatives, they were eliminated. The architects kept double glazing for its sound insulating characteristics on the west wall of the campus that faced a busy street. For the rest of the campus, single, clear glazing was used.

The final conclusions of the PowerDOE simulation were to:

- Increase the wall and roof insulation levels.
- Install operable windows for maximum natural ventilation potential.
- Install single pane clear glazings with exterior overhangs.
- Install automatic and manual daylighting/lighting dimming controls.
- Install clerestory windows to improve interior daylighting quality.
- Install high-efficiency air-source heat pumps.

These measures were predicted to result in a 43% annual utility savings ($15,300) over a minimum Title 24 building.

Figure 20: Building Characteristics for Base Case and Proposed Design

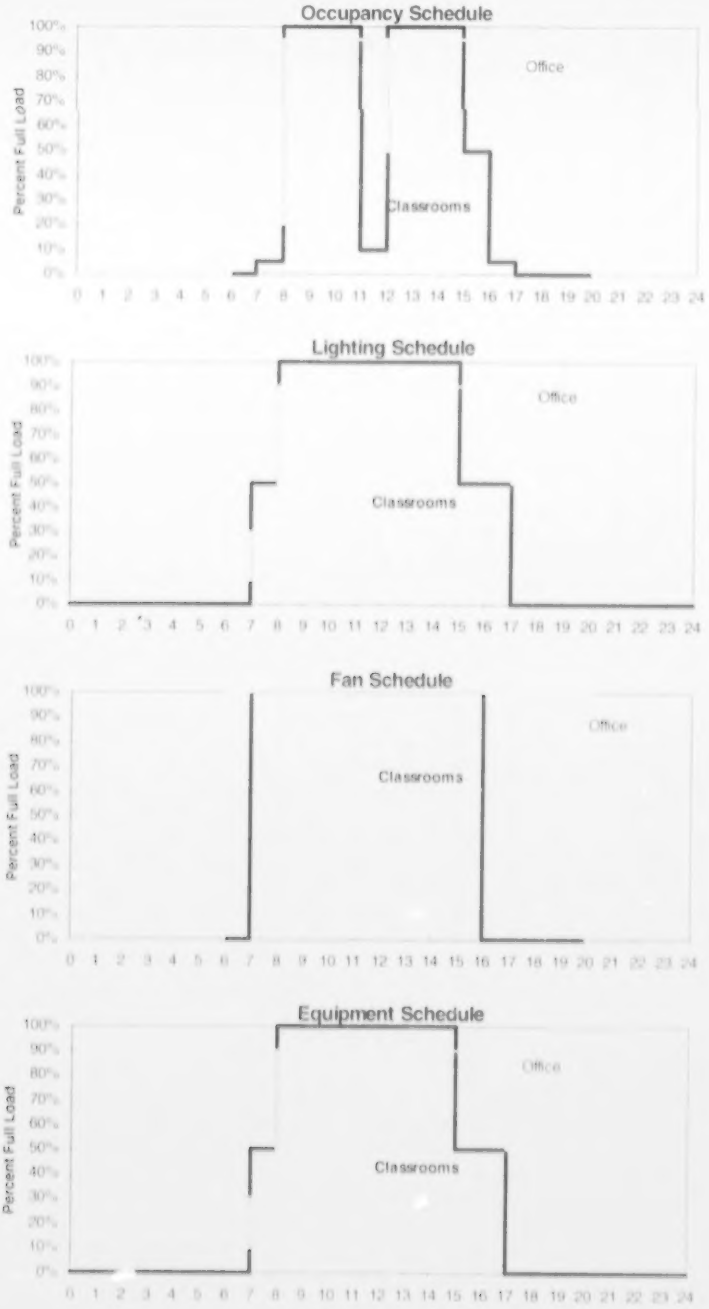
Building Characteristics
Newport Coast Elementary School

	TITLE 24 Base Case	As-Design*
ARCHITECTURAL FEATURES		
Gross Modeled Area	47,000 sqft	**
Orientation	site main axis = 20° east of	**
campus arrangement	eight separate buildings	**
Exterior Wall Type	2x4 wood frame with R11	2x6 wd frame, R19 batt + ext
Opaque Wall U-value (R-	U=0.092 (R11)	U=0.037 (R27)
Roof U-value (R-value)	U=0.092 (R11)	U=0.024 (R42)
Exterior Roof Color	0.7 (medium dark)	**
Window Type	sgl-glazed clear (N), gray	dbl clear @ west, else sgl
Assumed frame type	aluminum	architectural steel
U-Value (incl. frame	1.23	1.23 (non-west), 0.64 (west)
Shading Coefficient	0.94 (north), 0.71 (non-north)	0.94 (non-west), 0.81 (west)
Exterior Overhangs	none	2 to 4 ft deep at most
HVAC SYSTEM		
HVAC System Type	Air-cooled split DX/Furnace	High Eff. Air-cooled Heat
Cooling / Heating Setpoint	75F / 72F	**
Cooling Design Temps.	75DB / 82DB / 70WB	**
Heating Design Temps.	72DB / 40DB	**
Outside Air Supply	15 CFM/person	**
Coil Leaving Temperature	55 F	**
Fan Static (supply only)	0.75 in	**
Economizer	none	dry-bulb
Cooling Equip Efficiency	10 SEER	12 SEER
Heating Equip Efficiency	78% AFUE	2.6 COP @ 47°F
BUILDING OPERATION AND INTERNAL LOADING		
Classroom Occupancy	8am-4pm, Mon-Fri, Sep 15-Jun15 *(see Fig. 3.2 below)*	
Office Occupancy Schedule	7am-5pm, Mon-Fri, Sep 15-Jun15 *(see Fig. 3.2 below)*	
Lighting & Equipment	follows occupancy in classrooms and offices *(see Fig. 3.2*	
Fan Schedule	follows occupancy in classrooms and offices *(see Fig. 3.2*	
Internal Loads		
Lighting System Type	T-8 lamps, elect. ballasts,	T-8's, elect. ballasts,
Lighting Power Density	2.0 classrooms, 1.6 offices	2.2 classrooms, 1.9 offices
Receptacle Load	1.0 classrooms, 1.0 offices	**
Occupancy Density	30 (classrooms), 150 (offices)	**
Occupant Sens/Lat	200/130 (class) 250/200	**

* *proposed design is not final*

** *items unchanged from the TITLE 24 base case are marked with double asterisks*

Figure 21: Assumed Building Operations Profiles for Newport Coast Elementary



			Annual HVAC Energy						Energy Total			
	Lights	Misc Eq.	Heating	Heating	Cooling	Fans	Twr Fans	Pumps	Nat Gas	Elect	Total Site	Total Source
	MWh	MWh	Mbtu	MWh	MWh	MWh	MWh	MWh	Therm	MWh	Mbtu	Mbtu
Annual Energy Use												
0 Minimum Title24	130	60	227	0	26	15	0	0.5	2270	257	1105	2862
1 0+2x6 R19 ExtWalls	130	60	213	0	27	15	0	0.5	2130	258	1093	2854
2 1+2in PolyBd on Wall	130	60	200	0	27	14	0	0.5	2000	258	1080	2841
3 2+R-19 Roof***	130	60	171	0	26	14	0	0.5	1710	256	1046	2796
4 3+R-30 Roof	130	60	156	0	27	13	0	0.5	1560	256	1031	2782
5 4+2in PolyBd on Roof	130	60	148	0	27	13	0	0.5	1480	257	1023	2774
6 5+Design HVAC	130	60	134	0	22	13	0	0.5	1340	252	993	2711
7 6+Design LPD	141	60	128	0	24	13	0	0.5	1280	265	1034	2845
8 7+High Eff HP	141	60	39	9	24	12	0	0.5	390	273	971	2834
9 8+Classrm Ext Shading	141	60	39	11	18	12	0	0.5	390	269	956	2789
10 9+Dbl Clr Glass***	141	60	32	6	25	12	0	0.5	320	270	955	2801
11 9+Sgl Clr Glass	141	60	35	8	23	12	0	0.5	350	271	961	2813
12 11+Reduced Window Frame	141	60	34	7	25	12	0	0.5	340	272	961	2815
13 12+Manual DL Dimming	41	60	51	12	11	10	0	0.5	510	160	598	1693
14 13+ClrStory Glass Added	31	60	51	14	10	9	0	0.5	510	151	566	1596
15 14+Int Light Shelf***	29	60	51	14	10	9	0	0.5	510	149	560	1579
16 14+Dbl LoE Clr Glass***	36	60	46	12	7	8	0	0.5	460	149	555	1572
17 14+Sgl Solex Glass***	39	60	56	19	6	9	0	0.5	560	155	585	1643
18 14+Operable Windows	31	60	51	15	4	8	0	0.5	510	146	545	1533
19 18+Economizer	31	60	51	15	3	8	0	0.5	510	144	541	1521
20 19+Int Mass & Venting	31	60	51	18	3	8	0	0.5	510	147	552	1555
21 20+No HVAC in Classroom	31	60	31	1	6	6	0	0.4	310	130	474	1359
Incremental Savings *(percentage savings shown in parentheses, negative entries indicate increased use)*												
1 0+2x6 R19 ExtWalls	0 (0%)	0 (0%)	14 (6%)	0 (0%)	1 (-3%)	0 (1%)	0 (0%)	0 (0%)	140 (6%)	-1 (0%)	12 (1%)	8 (0%)
2 1+2in PolyBd on Wall	0 (0%)	0 (0%)	13 (6%)	0 (0%)	0 (-1%)	0 (2%)	0 (0%)	0 (0%)	130 (6%)	0 (0%)	13 (1%)	13 (0%)
3 2+R-19 Roof***	0 (0%)	0 (0%)	29 (13%)	0 (0%)	1 (3%)	1 (6%)	0 (0%)	0 (0%)	290 (13%)	2 (1%)	34 (3%)	45 (2%)
4 3+R-30 Roof	0 (0%)	0 (0%)	15 (7%)	0 (0%)	0 (-1%)	0 (2%)	0 (0%)	0 (0%)	150 (7%)	0 (0%)	15 (1%)	14 (0%)
5 4+2in PolyBd on Roof	0 (0%)	0 (0%)	8 (4%)	0 (0%)	0 (-1%)	0 (1%)	0 (0%)	0 (0%)	80 (4%)	0 (0%)	8 (1%)	8 (0%)
6 5+Design HVAC	0 (0%)	0 (0%)	14 (6%)	0 (0%)	5 (19%)	0 (0%)	0 (0%)	0 (0%)	140 (6%)	5 (2%)	31 (3%)	64 (2%)
7 6+Design LPD	-12 (-9%)	0 (0%)	6 (3%)	0 (0%)	-2 (-7%)	0 (-2%)	0 (0%)	0 (0%)	60 (3%)	-14 (-5%)	-41 (-4%)	-134 (-5%)
8 7+High Eff HP	0 (0%)	0 (0%)	89 (39%)	-9 (0%)	0 (1%)	1 (8%)	0 (0%)	0 (7%)	890 (39%)	-8 (-3%)	63 (6%)	11 (0%)
9 8+Classrm Ext Shading	0 (0%)	0 (0%)	0 (0%)	-2 (0%)	6 (22%)	1 (4%)	0 (0%)	0 (0%)	0 (0%)	4 (2%)	15 (1%)	45 (2%)
10 9+Dbl Clr Glass***	0 (0%)	0 (0%)	7 (3%)	5 (0%)	-7 (-27%)	0 (1%)	0 (0%)	0 (-1%)	70 (3%)	-2 (-1%)	1 (0%)	-12 (0%)
11 9+Sgl Clr Glass	0 (0%)	0 (0%)	4 (2%)	3 (0%)	-5 (-21%)	0 (-3%)	0 (0%)	0 (-1%)	40 (2%)	-3 (-1%)	6 (-1%)	-25 (-1%)
12 11+Reduced Window Frame	0 (0%)	0 (0%)	1 (0%)	1 (0%)	-1 (-5%)	0 (1%)	0 (0%)	0 (0%)	10 (0%)	0 (0%)	0 (0%)	-2 (0%)
13 12+Manual DL Dimming	100 (77%)	0 (0%)	-17 (-7%)	-5 (0%)	14 (52%)	2 (16%)	0 (0%)	0 (1%)	-170 (-7%)	111 (43%)	363 (33%)	1123 (39%)
14 13+ClrStory Glass Added	10 (8%)	0 (0%)	0 (0%)	-2 (0%)	1 (3%)	0 (1%)	0 (0%)	0 (0%)	0 (0%)	9 (4%)	32 (3%)	96 (3%)
15 14+Int Light Shelf***	2 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	6 (1%)	17 (1%)
16 14+Dbl LoE Clr Glass***	-5 (-4%)	0 (0%)	5 (2%)	2 (0%)	3 (12%)	2 (13%)	0 (0%)	0 (0%)	50 (2%)	2 (1%)	11 (1%)	24 (1%)
17 14+Sgl Solex Glass***	-4 (-3%)	0 (0%)	-5 (-2%)	5 (0%)	4 (15%)	1 (5%)	0 (0%)	0 (1%)	50 (-2%)	-4 (-2%)	-19 (-2%)	-47 (-2%)
18 14+Operable Windows	0 (0%)	0 (0%)	0 (0%)	-1 (0%)	6 (24%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)	6 (2%)	21 (2%)	63 (2%)
19 18+Economizer	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (3%)	0 (0%)	0 (0%)	0 (-1%)	0 (0%)	1 (0%)	4 (0%)	12 (0%)
20 19+Int Mass & Venting	0 (0%)	0 (0%)	0 (0%)	-3 (0%)	0 (2%)	0 (-1%)	0 (0%)	0 (0%)	0 (0%)	-3 (-1%)	11 (-1%)	-34 (-1%)
21 20+No HVAC in Classroom	0 (0%)	0 (0%)	20 (9%)	18 (0%)	-3 (-12%)	3 (18%)	0 (0%)	0.1 (20%)	200 (9%)	-17 (7%)	79 (7%)	196 (7%)
Cumulative Savings *(relative to Case 0, percentage savings shown in parentheses, negative entries indicate increased use)*												
1 0+2x6 R19 ExtWalls	0 (0%)	0 (0%)	14 (6%)	0 (0%)	-1 (-3%)	0 (1%)	0 (0%)	0 (0%)	140 (6%)	-1 (0%)	12 (1%)	8 (0%)
2 1+2in PolyBd on Wall	0 (0%)	0 (0%)	27 (12%)	0 (0%)	-1 (-4%)	0 (3%)	0 (0%)	0 (0%)	270 (12%)	-1 (0%)	25 (2%)	21 (1%)
3 2+R-19 Roof***	0 (0%)	0 (0%)	56 (25%)	0 (0%)	0 (-1%)	1 (9%)	0 (0%)	0 (0%)	560 (25%)	1 (0%)	59 (5%)	66 (2%)
4 3+R-30 Roof	0 (0%)	0 (0%)	71 (31%)	0 (0%)	-1 (-3%)	2 (11%)	0 (0%)	0 (0%)	710 (31%)	1 (0%)	74 (7%)	80 (3%)
5 4+2in PolyBd on Roof	0 (0%)	0 (0%)	79 (35%)	0 (0%)	-1 (-4%)	2 (12%)	0 (0%)	0 (0%)	790 (35%)	1 (0%)	82 (7%)	87 (3%)
6 5+Design HVAC	0 (0%)	0 (0%)	93 (41%)	0 (0%)	4 (15%)	2 (12%)	0 (0%)	0 (0%)	930 (41%)	6 (2%)	112 (10%)	151 (5%)
7 6+Design LPD	-12 (-9%)	0 (0%)	99 (44%)	0 (0%)	2 (8%)	1 (10%)	0 (0%)	0 (0%)	990 (44%)	-8 (-3%)	72 (6%)	17 (1%)
8 7+High Eff HP	-12 (-9%)	0 (0%)	188 (83%)	-9 (0%)	2 (9%)	3 (18%)	0 (0%)	0 (7%)	1880 (83%)	-16 (-6%)	135 (12%)	28 (1%)
9 8+Classrm Ext Shading	-12 (-9%)	0 (0%)	188 (83%)	-11 (0%)	8 (31%)	3 (22%)	0 (0%)	0 (7%)	1880 (83%)	-11 (-4%)	150 (14%)	73 (3%)
10 9+Dbl Clr Glass***	-12 (-9%)	0 (0%)	195 (86%)	-6 (0%)	1 (4%)	3 (23%)	0 (0%)	0 (6%)	1950 (86%)	-13 (-5%)	150 (14%)	61 (2%)
11 9+Sgl Clr Glass	-12 (-9%)	0 (0%)	192 (85%)	-8 (0%)	3 (11%)	3 (19%)	0 (0%)	0 (6%)	1920 (85%)	-14 (-5%)	144 (13%)	48 (2%)
12 11+Reduced Window Frame	-12 (-9%)	0 (0%)	193 (85%)	-7 (0%)	1 (6%)	3 (20%)	0 (0%)	0 (6%)	1930 (85%)	-14 (-6%)	144 (13%)	46 (2%)
13 12+Manual DL Dimming	89 (68%)	0 (0%)	176 (78%)	-12 (0%)	15 (58%)	5 (36%)	0 (0%)	0 (7%)	1760 (78%)	97 (38%)	507 (46%)	1169 (41%)
14 13+ClrStory Glass Added	99 (76%)	0 (0%)	176 (78%)	-14 (0%)	16 (60%)	5 (36%)	0 (0%)	0 (7%)	1760 (78%)	106 (41%)	539 (49%)	1265 (44%)
15 14+Int Light Shelf***	101 (78%)	0 (0%)	176 (78%)	-14 (0%)	16 (61%)	5 (37%)	0 (0%)	0 (7%)	1760 (78%)	108 (42%)	545 (49%)	1283 (45%)
16 14+Dbl LoE Clr Glass***	94 (72%)	0 (0%)	181 (80%)	-12 (0%)	19 (73%)	7 (49%)	0 (0%)	0 (7%)	1810 (80%)	108 (42%)	551 (50%)	1290 (45%)
17 14+Sgl Solex Glass***	95 (73%)	0 (0%)	171 (75%)	-19 (0%)	20 (75%)	6 (41%)	0 (0%)	0 (8%)	1710 (75%)	102 (40%)	520 (47%)	1219 (43%)
18 14+Operable Windows	99 (76%)	0 (0%)	176 (78%)	-15 (0%)	22 (84%)	7 (48%)	0 (0%)	0 (7%)	1760 (78%)	113 (44%)	560 (51%)	1329 (46%)
19 18+Economizer	99 (76%)	0 (0%)	176 (78%)	-15 (0%)	23 (87%)	7 (49%)	0 (0%)	0 (8%)	1760 (78%)	114 (44%)	564 (51%)	1341 (47%)
20 19+Int Mass & Venting	99 (76%)	0 (0%)	176 (78%)	-18 (0%)	23 (89%)	7 (44%)	0 (0%)	0 (6%)	1760 (78%)	110 (43%)	553 (50%)	1307 (46%)
21 20+No HVAC in Classroom	99 (76%)	0 (0%)	196 (86%)	-1 (0%)	20 (77%)	9 (63%)	0 (0%)	0.1 (26%)	1960 (86%)	128 (50%)	632 (57%)	1603 (53%)

Figure 22: PowerDOE Output - Preliminary Annual ENERGY Use
Newport Coast Elementary School

	Annual Utility Cost Total ($)				
	Nat Gas Total	Electric Energy	Electric Demand	Electric Total	Utility Total
Annual Costs					
0 Minimum Title24	$1,648	$19,764	$13,455	$33,943	$35,591
1 0+2x6 R19 ExtWalls	$1,571	$19,812	$13,476	$34,012	$35,583
2 1+2in PolyBd on Wall	$1,497	$19,812	$13,429	$33,965	$35,462
3 2+R-19 Roof***	$1,331	$19,692	$13,137	$33,553	$34,884
4 3+R-30 Roof	$1,247	$19,700	$13,120	$33,543	$34,790
5 4+2in PolyBd on Roof	$1,197	$19,702	$13,088	$33,514	$34,711
6 5+Design HVAC	$1,116	$19,329	$12,245	$32,298	$33,414
7 6+Design LPD	$1,093	$20,380	$12,837	$33,941	$35,034
8 7+High Eff HP	$469	$20,968	$13,240	$34,931	$35,400
9 8+Classrm Ext Shading	$469	$20,829	$12,922	$34,274	$34,743
10 9+Dbl Clr Glass***	$411	$20,770	$12,923	$34,417	$34,828
11 9+Sgl Clr Glass	$437	$20,843	$13,068	$34,636	$35,072
12 11+Reduced Window Frame	$427	$20,866	$13,022	$34,612	$35,039
13 12+Manual DL Dimming	$554	$12,304	$8,263	$21,240	$21,844
14 13+ClrStory Glass Added	$556	$11,581	$7,866	$20,170	$20,726
15 14+Int Light Shelf***	$557	$11,451	$7,774	$19,949	$20,506
16 14+Dbl LoE Clr Glass***	$515	$11,435	$7,352	$19,511	$20,026
17 14+Sgl Solex Glass***	$591	$11,893	$8,362	$20,979	$21,570
18 14+Operable Windows	$556	$11,104	$7,976	$19,804	$20,360
19 18+Economizer	$556	$11,014	$7,953	$19,691	$20,247
20 19+Int Mass & Venting	$556	$11,267	$8,229	$20,220	$20,776
21 20+No HVAC in Classroom	$405	$9,845	$6,183	$16,852	$17,257
Incremental Savings *(percentage savings shown in parentheses, negative entries indicate increased cost)*					
1 0+2x6 R19 ExtWalls	$77 (5%)	$-48 (0%)	$-21 (0%)	$-69 (0%)	$8 (0%)
2 1+2in PolyBd on Wall	$74 (4%)	$0 (0%)	$47 (0%)	$47 (0%)	$121 (0%)
3 2+R-19 Roof***	$166 (10%)	$120 (1%)	$292 (2%)	$412 (1%)	$578 (2%)
4 3+R-30 Roof	$84 (5%)	$-8 (0%)	$17 (0%)	$10 (0%)	$94 (0%)
5 4+2in PolyBd on Roof	$50 (3%)	$ 2 (0%)	$32 (0%)	$29 (0%)	$79 (0%)
6 5+Design HVAC	$81 (5%)	$373 (2%)	$843 (6%)	$1216 (4%)	$1297 (4%)
7 6+Design LPD	$33 (2%)	$-1051 (-5%)	$-592 (-4%)	$-1643 (-5%)	$-1610 (-5%)
8 7+High Eff HP	$614 (37%)	$-588 (-3%)	$-403 (-3%)	$-990 (-3%)	$-376 (-1%)
9 8+Classrm Ext Shading	$0 (0%)	$340 (2%)	$318 (2%)	$657 (2%)	$657 (2%)
10 9+Dbl Clr Glass***	$58 (4%)	$-142 (-1%)	$-1 (0%)	$-143 (0%)	$-85 (0%)
11 9+Sgl Clr Glass	$32 (2%)	$-215 (-1%)	$-146 (-1%)	$-361 (-1%)	$-329 (-1%)
12 11+Reduced Window Frame	$10 (1%)	$-23 (0%)	$46 (0%)	$23 (0%)	$33 (0%)
13 12+Manual DL Dimming	$-127 (-8%)	$8562 (43%)	$4759 (36%)	$13322 (39%)	$13195 (37%)
14 13+ClrStory Glass Added	$-2 (0%)	$723 (4%)	$397 (3%)	$1120 (3%)	$1118 (3%)
15 14+Int Light Shelf***	$-1 (0%)	$130 (1%)	$92 (1%)	$221 (1%)	$220 (1%)
16 14+Dbl LoE Clr Glass***	$41 (2%)	$146 (1%)	$514 (4%)	$659 (2%)	$700 (2%)
17 14+Sgl Solex Glass***	$-35 (-2%)	$-312 (-2%)	$-496 (-4%)	$-809 (-2%)	$-844 (-2%)
18 14+Operable Windows	$0 (0%)	$477 (2%)	$-110 (-1%)	$366 (1%)	$366 (1%)
19 18+Economizer	$0 (0%)	$90 (0%)	$23 (0%)	$113 (0%)	$113 (0%)
20 19+Int Mass & Venting	$0 (0%)	$-253 (-1%)	$-276 (-2%)	$-529 (-2%)	$-529 (-1%)
21 20+No HVAC in Classroom	$151 (9%)	$1322 (7%)	$2046 (15%)	$3368 (10%)	$3519 (10%)
Cumulative Savings *(relative to Case 0, percentage savings shown in parentheses, negative entries indicate increased cost)*					
1 0+2x6 R19 ExtWalls	$77 (5%)	$-48 (0%)	$-21 (0%)	$-69 (0%)	$8 (0%)
2 1+2in PolyBd on Wall	$151 (9%)	$-48 (0%)	$26 (0%)	$-22 (0%)	$129 (0%)
3 2+R-19 Roof***	$317 (19%)	$72 (0%)	$318 (2%)	$390 (1%)	$707 (2%)
4 3+R-30 Roof	$401 (24%)	$64 (0%)	$335 (2%)	$400 (1%)	$801 (2%)
5 4+2in PolyBd on Roof	$451 (27%)	$62 (0%)	$367 (3%)	$429 (1%)	$880 (2%)
6 5+Design HVAC	$532 (32%)	$435 (2%)	$1210 (9%)	$1645 (5%)	$2177 (6%)
7 6+Design LPD	$565 (34%)	$-616 (-3%)	$618 (5%)	$2 (0%)	$567 (2%)
8 7+High Eff HP	$1179 (72%)	$-1204 (-6%)	$215 (2%)	$-988 (-3%)	$191 (1%)
9 8+Classrm Ext Shading	$1179 (72%)	$-864 (-4%)	$533 (4%)	$-331 (-1%)	$848 (2%)
10 9+Dbl Clr Glass***	$1237 (75%)	$-1006 (-5%)	$532 (4%)	$-474 (-1%)	$763 (2%)
11 9+Sgl Clr Glass	$1211 (73%)	$-1079 (-5%)	$387 (3%)	$-692 (-2%)	$519 (1%)
12 11+Reduced Window Frame	$1221 (74%)	$-1102 (-6%)	$433 (3%)	$-669 (-2%)	$552 (2%)
13 12+Manual DL Dimming	$1094 (66%)	$7460 (38%)	$5192 (39%)	$12653 (37%)	$13747 (39%)
14 13+ClrStory Glass Added	$1092 (66%)	$8183 (41%)	$5589 (42%)	$13773 (41%)	$14865 (42%)
15 14+Int Light Shelf***	$1091 (66%)	$8313 (42%)	$5681 (42%)	$13994 (41%)	$15085 (42%)
16 14+Dbl LoE Clr Glass***	$1133 (69%)	$8329 (42%)	$6103 (45%)	$14432 (43%)	$15565 (44%)
17 14+Sgl Solex Glass***	$1057 (64%)	$7871 (40%)	$5093 (38%)	$12964 (38%)	$14021 (39%)
18 14+Operable Windows	$1092 (66%)	$8660 (44%)	$5479 (41%)	$14139 (42%)	$15231 (43%)
19 18+Economizer	$1092 (66%)	$8750 (44%)	$5502 (41%)	$14252 (42%)	$15344 (43%)
20 19+Int Mass & Venting	$1092 (66%)	$8497 (43%)	$5226 (39%)	$13723 (40%)	$14815 (42%)
21 20+No HVAC in Classroom	$1243 (75%)	$9819 (50%)	$7272 (54%)	$17091 (50%)	$18334 (52%)

Figure 23: PowerDOE Output - Preliminary Annual COST Results
Newport Coast Elementary School

In preparing the PowerDOE results for the District and their design team, D&ES visited a number of other schools in the District, and with accumulated electric energy bills, compared the electric energy unit cost for the Base Case Newport Coast School, the Proposed Newport Coast School, and four other elementary schools in the District. Figure 24 below shows the results of the comparison.

The unexpectedly low electric energy unit cost for Paularino school was noted, and could have a number of explanations. This school is a 1950's-60's design with large, glazed, movable panels for one wall of the classrooms, and operable clerestory windows. When visiting the school, it was noted that the teachers are effectively operating these design elements, so perhaps the school is historical proof of many of the design measures investigated for the Newport Coast Elementary School. On the other hand, it is also possible the electric data was missing another meter that records electric energy use at the school. Other than this anomaly, this school energy cost comparison makes clear the improvement in operating energy expenses the Newport Coast Elementary School represents for the District.

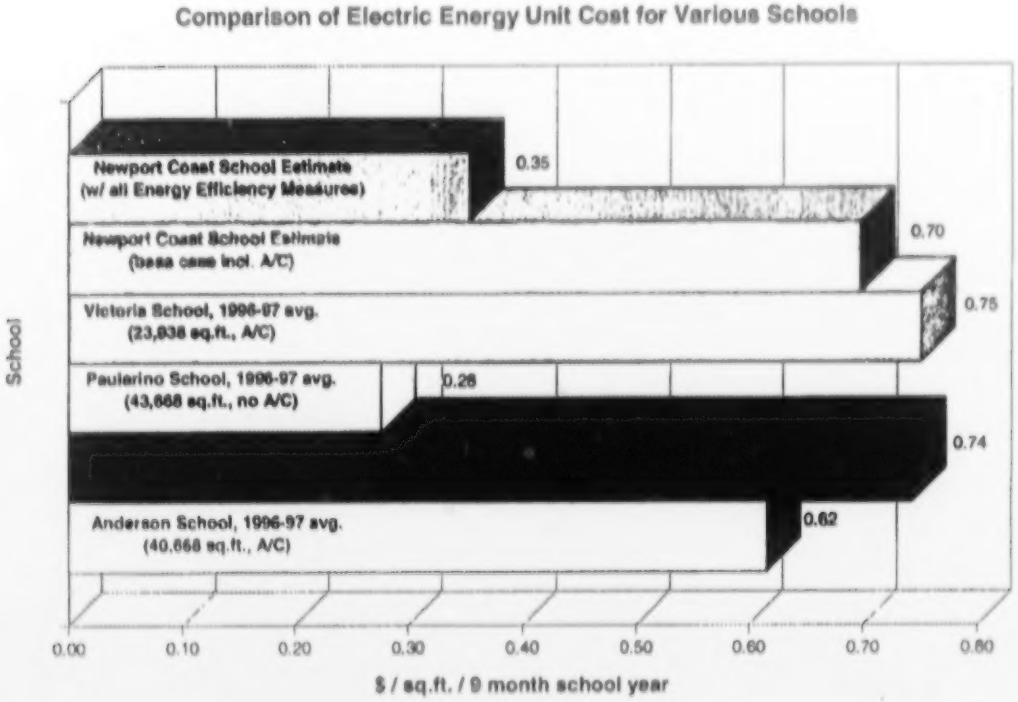


Figure 24: Comparison of Electric Energy Unit Costs for Newport Mesa Unified Elementary Schools

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Roof Color:

One other interesting result of the energy simulation was a discussion early in schematics with the design team and the land developer on the energy and interior temperature impacts of the red tile roofs. D&ES used a Back-to-Back classroom module and compared a roof with 70% absorptivity (the red tiled roof) with a lighter roof with 30% absorptivity, on a typical September day when the outside air temperature peaks at 75° F. The following figures show the simulated results, and compares the internal air temperatures in the north the south classrooms for a dark roofed classroom and an light roofed classroom, and also compares these temperatures to a conditioned space.

Average School Day Temperatures - September CTZ06
Newport Mesa United School District

		Lt. Roof Uncond, Roof Abs. = 30%			Dk. Roof Uncond., Roof Abs. = 70%		
	OSA	South Zone			North Zone		
Hour	(F)	Conditioned	Dk Rf, Uncond	Lt Rf, Uncond	Conditioned	Dk Rf, Uncond	Lt Rf, Uncond
1	63	77.5	80.0	78.3	74.5	74.5	74.4
2	63	77.2	79.6	78.0	74.2	74.2	74.1
3	62	76.9	79.3	77.7	73.9	73.9	73.8
4	62	76.5	78.9	77.3	73.6	73.6	73.5
5	61	76.3	78.6	77.1	73.4	73.4	73.3
6	61	76.0	78.3	76.8	73.2	73.2	73.1
7	63	74.2	74.5	73.8	72.4	72.2	72.1
8	66	77.1	73.3	73.6	75.6	74.2	74.1
9	70	77.6	77.4	76.0	77.1	74.3	74.3
10	73	77.9	80.0	78.9	77.7	76.8	76.8
11	75	78.0	81.1	79.2	77.8	77.5	77.4
12	75	78.3	83.3	81.2	78.0	78.1	78.1
13	75	78.5	84.6	83.0	78.1	79.1	79.1
14	75	78.6	85.4	83.9	78.1	78.6	78.6
15	74	78.3	84.2	82.8	77.9	78.0	78.0
16	72	85.1	89.2	86.9	80.2	80.3	80.2
17	69	83.7	87.4	85.2	78.9	79.0	78.9
18	67	82.3	85.7	83.6	78.1	78.1	78.0
19	66	81.0	84.1	82.2	77.3	77.3	77.2
20	66	80.0	82.9	81.2	76.6	76.6	76.5
21	65	79.2	82.0	80.3	76.1	76.1	76.0
22	65	78.7	81.4	79.8	75.7	75.7	75.6
23	64	78.2	80.8	79.3	75.3	75.3	75.2
24	63	77.8	80.4	78.9	75.0	75.0	74.9
Average (hours 12-15)		**78.4**	**84.4**	**82.7**	**78.0**	**78.5**	**78.4**

Figure 25: Average School Day Temperatures Comparing Roof Color Impact

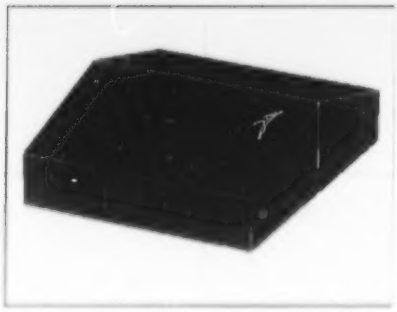

Figure 26: PowerDOE Back-to-Back Classroom Module Viewed From the South

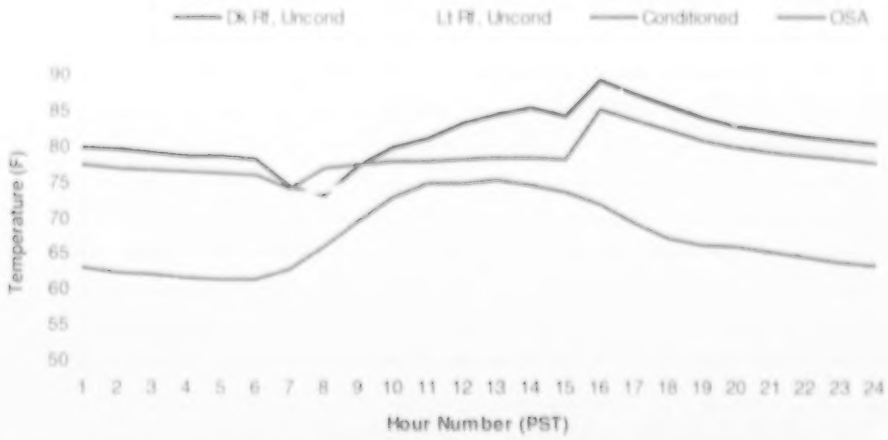

Figure 27: Average September Air Temperatures - South Classroom

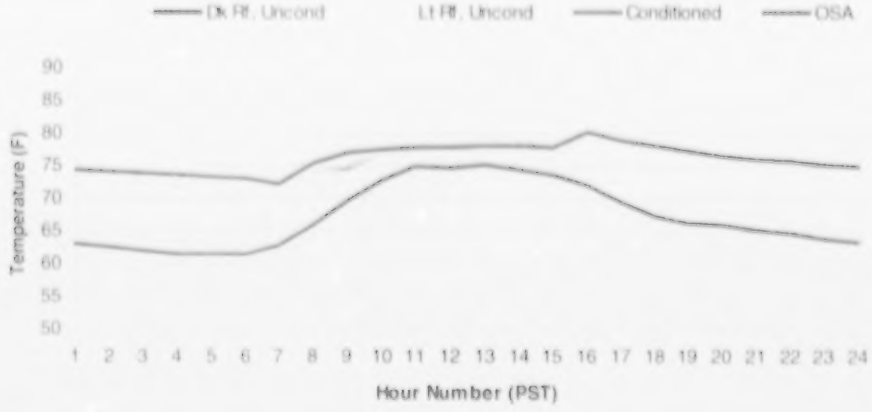

Figure 27: Average September Air Temperatures - North Classroom

The south classroom is impacted more by the roof color, with an average 1.7° F interior temperature difference, and as one would expect, increasing interior temperatures as

the afternoon progresses. The question for the design team was to compare the aesthetic value of the red tile roofs with the potential air conditioning costs for an average additional 1.7° F internal temperature. As the land developer would have no responsibility for operating expenses, the operating cost differential was not of great concern to them. They did offer the design team a range of red tiled roof colors to choose from, though of the light red to dark red options, none would approach the 30% absorptivity modeled.

Really the issue was a larger community design issue of understanding the energy impacts of community-wide design decisions. Roof color consistency is one of many decisions that a land developer can control. When you multiply an average 1.7° F increase in interior air temperature in what is typically the hottest month of the year, for 3,000 structures, the cost savings and pollution avoidance can be significant. The discussion on the energy impacts of roof color at the school was unfortunately too late in the process for this community.

Other Design Assistance Efforts:

D&ES contributed other design assistance efforts to this school project, though these cannot be discussed in this paper. In addition to what is explored above, D&ES assisted in securing a grant from the U.S. Department of Energy for a solar thermal domestic hot water collector system to meet a portion of the hot water need for the school. The DOE grant allows the District to place a renewable energy system onsite to model alternative energy sources.

D&ES also worked closely with the design team in fine tuning the lighting design, fixture choices and lighting control systems. Additionally, the design team was provided with a "Green" materials matrix for all major building components, and a commissioning guideline for the bid specifications. D&ES will act as the commissioning agent for the school, and will install monitoring equipment to retrieve energy and related data once the school is occupied and in use. As part of its involvement, D&ES will report final conclusions on the successful and the unsuccessful energy and environmental measures that were incorporated into the project. D&ES intends to follow up with the teachers and administrators at the school as well, gauging their reactions to the building's elements.

Conclusion:

This project represents one project in a portfolio of school related work with which Southern California Edison's Design and Engineering Services is involved. With the recent passage of a state wide school construction bond of $9.2 billion, and with local bond initiatives that almost double that amount of money, there is an unprecedented investment that will be made in school facilities in the next 30 years. In fact, it is estimated that $39 billion will be needed in California for new school construction and modernization in the next ten years.

The issues of energy use and the environment are primary issues for school design, and the Newport Coast Elementary School represents a test case of the benefits of integrating current energy modeling and analysis techniques into the school design process. It should not be forgotten, however, that other very fundamental design issues are of equal significance during this current opportunity to rethink our schools. Apart from issues of sustainable design, any discussion of new schools must include imagining the best environments for learning and for integrating developing minds into our society. Isolated, traditional school campuses with compartmentalized class layouts may not best serve how children learn, or how all children should learn. Also, they may not best serve how society needs to embrace children. Recent incidents of school violence make these discussions even more urgent. Optimization of a campus' operations is of little value if the fundamental underlying questions on how to improve education through new school design have not been asked and discussed.

Often a design project seems in retrospect to only vaguely have approximated all of the lofty intentions of the participants in the process, participants that include everyone from the architects and consultants, to the District officials, to the students and the teachers. It is always a challenge to maintain higher goals through what is often a bruising process. With the design assistance that D&ES brought to this process, an added effort was required by the design team to integrate an entirely new set of intentions into a complex process. The design team was consistently responsive to these added pressures, and graciously balanced competing interests when they arose. Ultimately, it is clear that without a client's early dedication to energy efficiency and environmental issues, little value can be derived from the sophisticated analysis tools used in this project. Setting a clear and widely supported sustainability agenda early in the process will go further to meeting the goal of reducing a building's impact on the earth than all of the sophisticated engineering tools used here.

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The following individuals contributed to this project, and each had a hand in the collaboration.

Project Team at Southern California Edison:

- Deborah Weintraub, AIA: Project Lead
- Tony Pierce, PE
- Gregg Ander, AIA
- Kelly Andereck, CSI
- Jon Reeves

Project Team at Perkins and Will:

- Courtney McLeod Golden
- Vincent Coffeen
- Ryan Hollien

- Gaylaird Christopher, AIA

Others:

- Marlin Addison, PowerDOE
- John Hill, Computational Fluid Dynamics
- Professor Hofu Wu, Daylight Modeling
- Nancy Clanton, PE, Lighting
- Chris Hammer, "Green" Materials

The Staff at the Newport Mesa Unified School District